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Benthic Macroinvertebrate Communities As Indicators Of River Health: An Enlightening Experience In Langting Stream, North East India

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Abstract:

The first time ever biomonitoring study of River Langting in Dima Hasao District, Assam, India endeavoured at evaluating its water in different stretches using macroinvertebrates as bioindicators. During pre-monsoon, monsoon, post monsoon and winter between March 2021 to February 2022, macroinvertebrates were collected from selected sites. A total of 9 families of macroinvertebrates recorded from 8 orders; the most abundant species recorded was *Orthetrum Sabina* in winter period and the least species was *Baetis sp.*in monsoon and post-monsoon.

The biotic indices like Shannon-Wiener Diversity Index (H), Simpson's Diversity index(D), Margalef Diversity index(Ma), Family Biotic Index(FBI) have shown relatively better quality of water of the River Langting in the stations S1, S2 than that in the stations S3, S4 and S5. Presence/absence and abundance of certain macroinvertebrates can provide information about health of the river. The diversity indices were calculated for the benthic macroinvertebrates of different sampling stations. H (Shannon-Wiener Diversity index) of benthic macroinvertebrate in Langting river was ranged from 1.76 in winter at S4 to 2.22 in pre-monsoon at S1. D (Simpson's Diversity index) in Langting river was recorded minimum 0.81 at S4 in monsoon to a maximum 0.89 at S1and S2 in pre-monsoon. Ma (Margalef Diversity index) in Langting river was recorded minimum with 1.30 in winter at S4 to a maximum of 2.06 in monsoon at S1.

Keywords: Langting river, Dima Hasao district, macro-invertebrates, Diversity index, water quality.

Introduction:

Fresh water habitats are the most endangered ecosystem on account of modern urbanization and industrialization(Armitage *et al*., 1983), facing severe threat due to various anthropogenic activities (Hellawell, 1986; Metcalfe, 1989 and ultimately disturb the ecological balance and loss of aquatic biodiversity (Jewitt, 2002; Hassan *et al*., 2005). The goods and services of fresh water systems provide livelihood to millions of people including supply of fresh water (Barathy *et al*., 2021). In most developing countries, approximately 90% of wastewaters are discharged into rivers and streams with partial or no treatment (Ashton, 2007) and in some areas people still consume polluted and contaminated water without any treatment (Arthington *et al*., 2010). Accordingly, surface water pollution is increasing and as a result human and ecosystem health is deteriorating gradually (Aazami *et al*., 2020). Therefore, assessment of river health is indispensible.

. The conventional physical and chemical measures of water quality might help determining water contamination, but it is expensive in terms of equipment and time and often offers only limited information. In addition, Biological monitoring is an effective tool to assess the ecological quality of a watercourse and provides an integrated measure of water quality by integrating the multiple effects of stressors, including chemical, physical and biological (Extence *et al*., 2013; Marzin *et al*., 2012). It has established itself to be a vital tool for assessing and managing lotic systems (Hynes, 2007; Bonada *et al*., 2006) and has been particularly used in developing countries (Resh, 2007; Mason, 1996). Standard physico-chemical water quality methods in conjunction with biomonitoring tool should be undertaken for comprehensive evaluation of freshwater ecosystem.. Nowadays, bioindicators, which comprise of wide range of organisms, are utilized in biomonitoring to determine the status of stream habitats. The use of living organism for monitoring water quality originated in Europe early in this century and it is widely used (Cairns and Pratt, 1993; Metcalfe-Smith, 1994). Studies on the potential use of benthic macroinvertebrates as bioindicators for river ecosystems also have been broadly reported in literature (Rosenberg and Resh, 1993; Mustow, 2002; Ganguly *et al*., 2018; Aazami *et al*., 2019; Mahmoud and Riad, 2020). Many countries have a long history of using macroinvertebrates to monitor the ecological status of river ecosystems (Hellawell, 1986; Li *et al.*, 2010; Birk *et al*., 2012; Carter *et al*., 2017; Musonge *et al.*, 2020; Akyildiz and Duran, 2021; Eriksen *et al*., 2021).

The ever increasing human population and intensification of agricultural and industrial activities in India has posed a serious hindrance in dealing with water pollution. The main source of pollutants is release of untreated domestic and industrial effluents (Anonymous, Central Pollution Control Board, 2010). This necessitates periodic monitoring and evaluation of the quality of lotic waters to implement corrective measures.

Although Dima Hasao, a hill district in Assam is relatively free from pollution as there are no major industries in the district, but mining activities and organic pollution due to household generated waste materials gradually polluting in certain areas. Langting stream of Dima Hasao district is a tributary of Doyang river. People living near the river directly pollute the water by taking bath, washing clothes, vehicles and utensils in it. The healthy aquatic ecosystem is dependent on the physico-chemical and biological characteristics of water (Venkatesharaju *et al*., 2010). Cultivation of seasonal crops at the bank and catchment area of the river strengthen the economic status of the riverine villagers. Since there is paucity of data on this important stream of Dima Hasao district, Assam, it is an attempt to generate baseline information on the benthic macroinvertebrate community of the stream and monitor water quality using aquatic macroinvertebrates as bioindicators. Various biotic indices such as Biological Monitoring Working Party Score (BMWP), Hilsenhoff family biotic index (HFBI). It is expected that this study would give insight of the water quality of the river, which is supposed to be pristine.

The survival of all living organisms, the maintenance of aquatic ecosystem integrity and socio-economic development necessitates a sustainable supply of clean and safe water (Hassan *et al*., 2005; UN-Water, 2008; 2011; 2012) and therefore, it is very important to assess the quality of river water. Therefore, Present study has been conducted in Langting stream of Dima Hasao district of Assam with the following objectives:

* To assess the macro-invertebrate diversity of Langting stream
* Assessment of the water quality of the riverine system on the basis of evaluation of macro-invertebrate diversity index.

Materials and Methods:

Study area:

The selected study area is the Langting stream, covering a stretch of 8 km. Langting stream originates from Semkhor village, the border area of Nagaland, Manipur and Dima Hasao. Langting stream confluents to Diyung river (originates from Borail range), is about 38 km. from Lumding(hojai district, Assam). For study and data collection, The stretches were demarcated into five sampling stations viz: S_1, S_2, S_3, S_4 and S_5 (Fig.1 and Fig.2). These study sites were based on accessibility and physical habitat similarity.

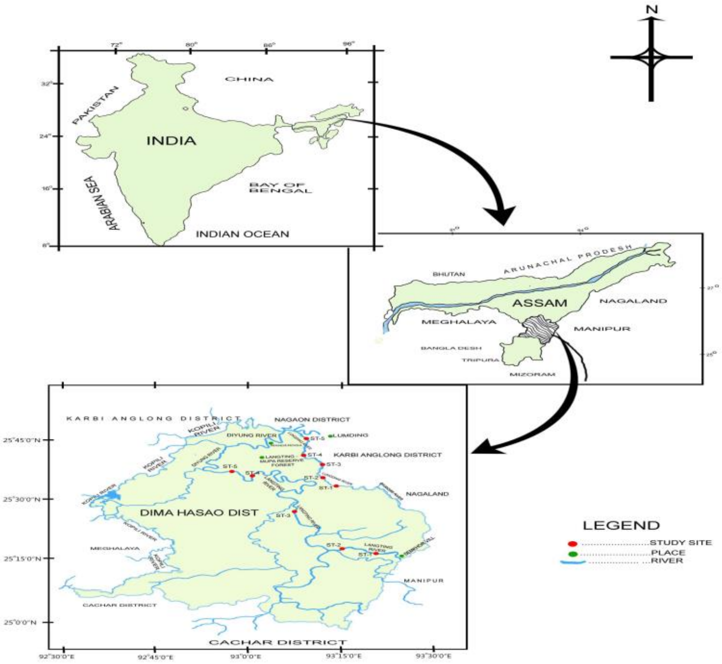


Fig.1: Location of Langting town in Dima hasao district, India; map showing selected stream and sampling sites.

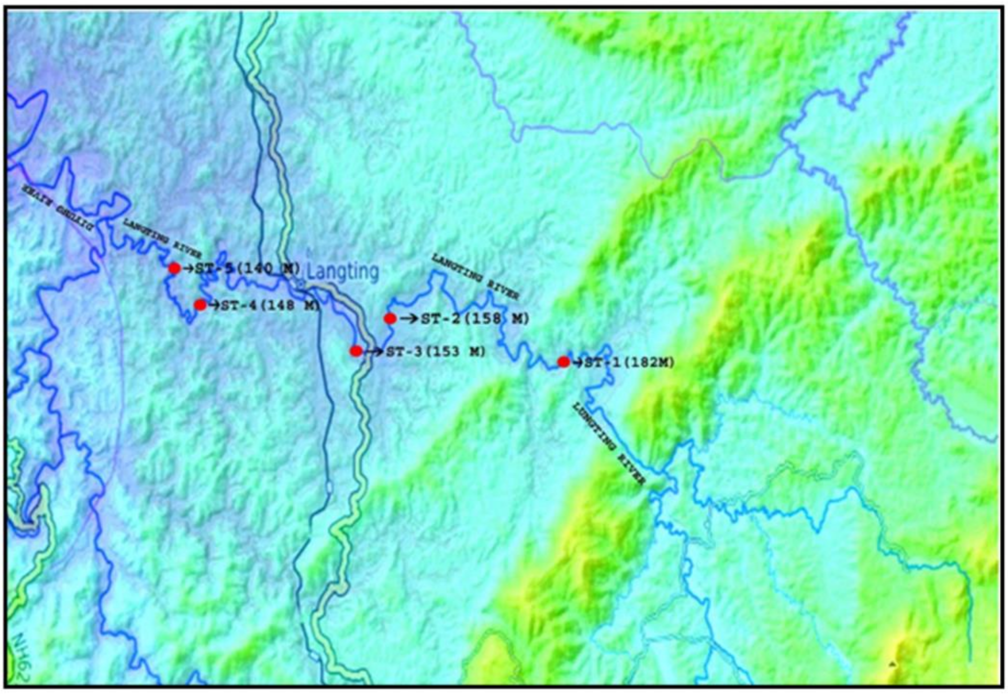


Fig-2: Location of sampling sites of Langting river

Physical status of selected streams:

Physical features of instream and river banks: Longitude, latitude of each station was measured with the help of GPS were recorded (Table-1).

Table-1: Longitude, latitude and altitude of five stations

Sampling site	Name of the station	GPS position	Altitude(m)
S_1	Langting I	25°30′25″N 93°46′29″E	155
S_2	Langting II	25°26′50″N 93°48′20″E	153
S_3	Langting III	25°28′52″N 93°49′9″E	147
S_4	Langting IV	25°26′40″N 93°6′99″E	145
S_5	Langting V	25°29′48″N 93°6′45″E	140

Period of study: From March 2021 to February 2022.

Methodology:

Water Sampling:

Water samples were collected and stored in thoroughly sterilized bottles on seasonal basis for one year (March-2021 to February -2022) from the five sampling stations of two selected streams.

Collection of water samples was undertaken according to the standard methods for examination of water (APHA, 1995). Water samples used for the analysis of chemical variables, were collected in plastic container of 250 ml. The Institute for Water Research glassware acid wash protocol was fully observed in preparing sampling bottle before each field trip. Water samples were collected facing upstream of the river as recommended in APHA *et al.*, (1971) and the bottles were filled to the neck allowing no head space and transported to the laboratory in an ice-filled cooler box. Samples were preserved at 4 ^{0}C in the laboratory for chemical analysis. All chemical analyses were performed within 24 hours of sample collection. Analyses were conducted for three replicates for each sample and averaged. This method was adopted due to the fact that average readings were more representatives besides reducing variability in the measured results.

Identification of macroinvertebrates:

The macroinvertebrates were sorted and identified as suggested by Pennak (1989) and Edmondson (1993) and also using online published journals, with consultation of experts. Digital Camera was used to document larger specimens, while Stereomicroscope for smaller samples.

Statistical analysis:

(A) Statistical tools used for studying the Physico-chemical parameters:

(i) Seasonal Variations and average seasonal variations of physico-chemical parameters in Langting stream was calculated using Microsoft Excel.

(ii) To establish the degree of association between various physical and chemical parameters, Pearson's correlation matrix was calculated using XLSTAT.

(B) Statistical tools used for studying the Macro-invertebrates assemblage Formulae to calculate the diversity:

To evaluate the divergent water quality and diversity of macro-invertebrates in the selected stream , the correlation matrix between physico-chemical parameters and macro invertebrate density for each station were calculated using XLSTAT and the diversity indices like H (Shannon-Wiener Diversity index), D(Simpson's Diversity index), Ma(Margalef Diversity index), were calculated using

EXCEL. Family Biotic Index of the species was also accomplished.

The different formulae used to calculate the diversity indices are:

(i) Shannon-Wiener Diversity Index (H) (Shannon and Wiener, 1963)

$$H = -\sum_{s=1}^{s} (p_i) log p_i)$$

Where "p_i" is the proportion of individuals in the "i^{th}" taxon of the community and "s" is the total number of taxa in the community

(ii) Simpson's Diversity index (Simpson, 1949):

$D = 1-[\Sigma n_i (n_i -1)] / N (N-1)$

$n_i =$ Number of individuals belonging to i species

N =Total number of individuals

(iii) Margalef Diversity index(Margalef, 1958):

It is calculated as

Margalef's index Ma = (S-1) / log N

Where, S = Total number of taxa

N = Total number of individuals.

(iv) Family Biotic Index of the species:

The biotic index i.e. FBI (Family Biotic Index) was made use of to further assess the water quality and diversity of macro-invertebrates in the streams and calculated as per the following formula:

FBI = $\sum x_i.t_i / n$, (Plafkin *et al.*, 1989, Barbour *et al.*, 1999) where $x_i =$ no. of individuals within a taxon, t_i tolerance value of a taxon, and n = total no. of organisms in the sample.

The values demarcated in Tolerance while calculating FBI viz. listing of tolerance values that range from 0 for organisms very intolerant of organic wastes to 10 for organisms very tolerant of organic wastes, have been taken from standard protocols provided by Hilsenhoff (1987)(Table-2).

Table-2-Result interpretation chart for family biotic index (adapted from Hilsenhoff, 1977)

Biotic Index	Water quality	Degree of organic pollution
0.00–3.50	Excellent	No apparent organic
3.51–4.50	Very good	Possible slight organic pollution
4.51–5.50	Good	Some organic pollution
5.51–6.50	Fair	Fairly significant organic pollution
6.51–7.50	Fairly poor	Significant organic pollution
7.51–8.50	Poor	Very significant organic pollution
8.51–10.0	Very poor	Severe organic pollution

Result:

Salient feature of physico-chemical parameters of River Langting:

Seasonal variations of physicochemical factors from different sampling sites have been given in Table- 3. The flow of the river water was maximum in monsoon and minimum in pre-monsoon. Air and water temperature shows an increasing trend towards the monsoon season and found to be minimum in winter in all the stations. The TDS values were maximum in in post-monsoon and minimum in winter. Conductivity was low during post-monsoon season and highest in monsoon as recorded from all the stations. Turbidity was found to be minimum in winter but maximum in monsoon in all the stations. pH values were found to be maximum in winter and minimum in monsoon. DO was found to be maximum in monsoon and minimum in post-monsoon, whereas the phosphate value was maximum in pre-monsoon and minimum in post-monsoon. Free carbon dioxide was found to be maximum in monsoon and minimum in post-monsoon. Alkalinity was found to be highest towards monsoon season and lowest in winter season.

Table 3: Seasonal variation (mean±S.D) of the physicochemical parameters in River Langting during 2021-2022.

Parameters	Seasons	St-I	St- II	St-III	St-IV	St-V	Mean
Flow(m/sec)	Pre monsoon	0.18	0.15	0.2	0.15	0.13	0.16±0.03
	Monsoon	0.36	0.27	0.44	0.25	0.17	0.3±0.1
	Post-monsoon	0.19	0.16	0.21	0.16	0.17	0.17±0.03
	Winter	0.19	0.18	0.23	0.18	0.14	0.19±0.03
Air temp(ºC)	Pre monsoon	23.97	23.49	23.25	22.78	23.61	23.42±0.44
	Monsoon	30.4	29.79	29.49	28.9	29.94	29.7±0.56
	Post-monsoon	19.71	19.32	19.12	18.74	19.42	19.26±0.36
	Winter	16.93	16.59	16.42	16.09	16.67	16.54±0.31
Water temp(ºC)	Pre monsoon	22.1	21.6	21.4	21	21.8	21.58±0.41
	Monsoon	25.6	25.1	24.9	24.3	25.2	25.02±0.48
	Post-monsoon	17.4	17.1	16.9	16.6	17.2	17.04±0.3
	Winter	15.3	15.5	14.7	15	15.7	15.24±0.4
TDS(mg/L)	Pre monsoon	250	268	278	245	297	267.6±21.17
	Monsoon	370	309	378	345	379	356.2±29.74
	Post-monsoon	398	394	379	354	323	369.6±31.25
	Winter	212	203	199	223	226	212.6±11.89
Conductivity(µs/cm)	Pre monsoon	219.76	217.56	221.96	224.16	223.02	221.29±2.64
	Monsoon	231.68	229.36	234	236.315	235	233.27±2.77
	Post-monsoon	165.22	164.74	168.06	169.73	168.76	167.3±2.21
	Winter	170.24	168.54	171.94	173.64	172.66	171.4±2.03
Turbidity	Pre monsoon	2.36	3.0	3.26	2.25	4.07	2.99±0.74
	Monsoon	4.81	3.09	3.01	2.34	3.41	3.33±0.91
	Post-monsoon	3.9	3.16	2.72	2.85	2.54	3.03±0.53
	Winter	2.81	3.19	2.59	3.15	2.57	2.86±0.3
pH	Pre monsoon	7.43	7.30	7.5	7.42	7.48	7.43±0.08
	Monsoon	7.08	7.23	7.45	7.30	7.40	7.29±0.15
	Post-monsoon	7.76	7.42	7.65	7.54	7.62	7.6±0.13
	Winter	8.03	7.64	7.6	7.6	7.81	7.74±0.19
D.O.(mg/l)	Pre monsoon	7.15	7.22	7.07	7.14	7.12	7.14±0.05
	Monsoon	7.17	7.24	7.1	7.17	7.15	7.17±0.05
	Post-monsoon	5.11	5.16	5.06	5.11	5.1	5.11±0.04
	Winter	6.22	6.28	6.16	6.22	6.2	6.22±0.04
Phosphate	Pre monsoon	0.04	0.03	0.039	0.032	0.04	0.04±0
	Monsoon	0.033	0.029	0.025	0.028	0.024	0.03±0
	Post-monsoon	0.024	0.027	0.026	0.026	0.021	0.02±0
	Winter	0.032	0.031	0.029	0.027	0.026	0.03±0
Free CO_2(mg/l)	Pre monsoon	4.44	4.51	4.7	4.05	4.18	4.38±0.26
	Monsoon	5.3	5.26	5.27	4.67	4.87	5.07±0.29
	Post-monsoon	4.55	4.54	4.47	4.43	4.51	4.5±0.05

	Winter	4.72	4.89	5.27	4.81	4.74	4.89±0.22
Alkalinity(mg/l)	Pre monsoon	130.43	130.4	125.53	135.38	137.4	131.83±4.67
	Monsoon	164.8	172.05	144.79	166.03	167.14	162.96±10.52
	Post-monsoon	103.9	112.7	104.7	114.52	112.45	109.65±4.96
	Winter	80.9	81.32	87.88	90.58	95.78	87.29±6.32

Relationship between hydrological attributes:

The pair wise correlation of physicochemical parameters of Langting river is presented in Table(4). In the present study, air and water temperature showed significant positive correlation (r=0.99). Water temperature is positively correlated with turbidity(r=0.5), pH(r=0.96), TDS(r=0.88), DO(r=0.76), CO_2(r=0.28), phosphate(r=0.25) and alkalinity(r=0.97). Water temperature is negatively correlated with conductivity(r=-0.94). Turbidity is positively correlated with pH(r=0.24), TDS(r=0.76), phosphate(r=0.06) and alkalinity(r=0.65). It is negatively correlated with conductivity(r=-0.69), DO(r=-0.19) and free CO_2(r=-0.29). pH is negatively correlated with conductivity DO (r=-0.83) and positively correlated to TDS(r=0.73), DO(r=0.91), CO_2(r=0.44), phosphate(r=0.22) and alkalinity(r=0.88). TDS is also positively correlated with DO(r=0.43) phosphate(r=0.47) and alkalinity(r=0.89). TDS is negatively correlated with conductivity(r=-0.85) and free CO_2(r=-0.17). Conductivity is positively correlated with phosphate(r=0.02) and negatively correlated to DO(r=-0.53) free CO_2 (r=-0.33) and alkalinity(r=-0.99). Dissolved oxygen is positively correlated with free CO_2(r=0.5), phosphate(r=0.28 and alkalinity(r=0.60). Free carbon dioxide is negatively correlated with phosphate(r=-0.69) and positively correlated with alkalinity(r=0.29). Phosphate is also positively correlated to alkalinity(r=0.10).

Table 4- Correlation between the physicochemical parameters in five stations of Langting stream:

Parameters	Flow(m/s)	Air temp. (˚C)	Water temp(˚C)	TDS (µs/cm)	Conductivity (µs/cm	Turbidity (NTP)	pH	DO(ppm)	PO_4	Free CO_2 (mg/l)	Alkalinity(mg/l)
Flow(m/s)	1.00										
Air temp. (˚C)	0.07	1.00									
Water temp(˚C)	-0.21	0.96	1.00								
TDS(µs/cm)	0.47	0.60	0.45	1.00							
Conductivity (µs/cm)	-0.19	-0.62	-0.59	0.03	1.00						
Turbidity(NTP)	0.05	0.99	0.96	0.54	-0.64	1.00					
pH	0.24	0.44	0.33	0.90	0.37	0.39	1.00				
DO(ppm)	-0.51	0.17	0.33	-0.68	-0.63	0.24	-0.74	1.00			
PO_4	0.65	0.69	0.49	0.49	-0.62	0.72	0.29	0.02	1.00		
Free CO_2	0.79	0.35	0.16	0.45	-0.60	0.31	0.04	-0.19	0.60	1.00	
Alkalinity	-0.99	-0.19	0.08	-0.54	0.28	-0.16	-0.26	0.48	-0.69	-0.87	1.00

Benthic macroinvertebrate:

Abundance of Benthic macroinvertebrate:

In the study 10 species belonging to 3 phylums, 5 classes, 8 orders, 9 families of benthic macroinvertebrates have been recorded in Langting. Table- 5 and figure-3 show the taxonomic diversity of identified benthic macroinvertebrates of river Langting.

In Langting river, the phylum Annelida included a single class (Clitellata) with one order Haplotaxida; phylum Arthropoda included the two classes (Insecta and Malacostraca) of orders- Hemiptera, Odonata, Ephemeroptera, Coleoptera and Decapoda. Phylum Mollusca included two classes (Gastropoda and Bivalvia) of three orders Mesogastropoda, Unionoida and Architaenioglossa.

A total number of 1875 benthic macroinvertebrates have been collected from March 2021-February 2022 in Langting river of which 519, 397, 416 and 543 were collected during pre-monsoon, monsoon, post-monsoon and winter respectively(Table-6). In Langting river, the most abundant species recorded was *Orthetrum Sabina* in winter period and the least species was *Baetis sp.*in monsoon and post-monsoon.

Table 5- List of Benthic macroinvertebrates found in Langting river:

Sl no.	Name of genus/species	Phylum	Class	Order	Family
1	*Dragonfly(nymph)*	Arthropoda	Insecta	Odonata	Aeshnidae (Rambur,1842)
2	*Baetis sp.*(Leach, 1815)	Arthropoda	Insecta	Ephemeroptera	Baetidae
3	*Ilyocoris cimicoides* (Linnaeus, 1758)	Arthropoda	Insecta	Hemiptera	Naucoridae
4	*Maydelliathelphusa lugubris* (Wood-Mason, 1871)	Arthropoda	Malacostraca	Decapoda	Gecarcinucidae
5	*Lamellidens marginalis* (Lamarck,1819)	Mollusca	Bivalvia	Unionoida	Unionidae
6	*Pila globosa* (right spiral) (Swainson, 1822)	Mollusca	Gastropoda	Architaenioglossa	Ampullariidae
7	*Paludomus conica* (Gray, 1834)	Mollusca	Gastropoda	Mesogastropoda	Thiaridae
8	*Melanoides tuberculata* (O.F.Muller,1774)	Mollusca	Gastropoda	Mesogastropoda	Thiaridae
9	*Tubifex tubifex* (O.F.Muller, 1774)	Annelida	Clitellata	Haplotaxida	Naididae
10	*Orthetrum Sabina* (Drury,1770)	Arthropoda	Insecta	Odonata	Libellulidae

Table 6-Seasonal variations in the number of benthic macroinvertebrates in Langting stream:

Taxa	Pre-monsoon					Monsoon					Post-monsoon					Winter				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Dragonfly(nymph)	19	17	0	0	0	14	13	0	0	0	14	13	0	0	0	18	16	0	0	0
Baetis sp.	14	15	1	1	0	11	12	1	1	0	11	12	1	1	0	14	15	1	1	0
Ilyocoris cimicoides	14	14	1	0	2	11	11	1	0	2	22	11	1	0	2	28	14	1	0	3
Maydelliathelphusa lugubris	13	16	4	6	0	10	12	4	0	3	10	12	4	0	3	13	15	5	0	4
Lamellidens marginalis	14	12	6	9	10	5	9	5	6	7	6	9	5	6	7	8	12	6	8	9
Pila globosa(right spiral)	14	15	10	16	17	11	12	7	12	13	11	12	10	12	13	14	15	13	15	16
Paludomus(P) conica	11	9	10	15	16	8	6	7	12	12	8	6	10	12	15	11	8	13	15	20
Melanoides tuberculata	8	7	14	14	15	5	5	11	11	12	5	5	11	11	12	7	6	14	14	15
Tubifex tubifex	7	6	17	19	22	5	5	13	14	16	5	5	13	15	15	6	6	16	20	20
Orthetrum Sabina	3	0	17	24	25	1	1	21	23	24	1	1	20	22	23	1	1	26	28	30
Total	117	111	80	104	107	79	84	68	77	88	92	84	73	78	89	121	110	95	102	116

Density of Benthic macronvertebrate:

The density of benthic macro invertebrates had shown (Table-7) seasonal fluctuation - in pre monsoon, the range was from 20 no./m^2 at S3 to 29.25 no./m^2 at S1. In monsoon the minimum was recorded with a 17 no./m^2 at S3 to maximum 22 no./m^2 at S5. The maximum and minimum density of benthic macroinvertebrate in post monsoon were found as 23 no./m^2 at S1 and 18.25 no./m^2 at S3. In winter maximum with a 30.25 no./m^2 at S1 and minimum with a 23.75 no./m^2 at S3.. The annual mean fluctuations of density of Langting River were recorded in the increasing order of S1 (25.56 no./m^2) > S5 (25.00 no./m^2) > S2 (24.31 no./m^2) > S4 (22.56 no./m^2) > S3 (19.75no./m^2).

Table-7 -Mean density of benthic macroinvertebrates (no. /m^2):

Seasons	Langting				
	S1	S2	S3	S4	S5
Pre-monsoon	29.25	27.75	20	26	26.75
Monsoon	19.75	21	17	19.25	22
Post-monsoon	23	21	18.25	19.5	22.25
Winter	30.25	27.5	23.75	25.5	29
Annual mean	25.56	24.31	19.75	22.56	25.00

Relationship between hydrological attributes and macroinvertebrate:

Macroinvertebrates had a significant inverse relationship with water velocity, TDS, conductivity and free CO_2 but positively correlated with water temperature, turbidity, pH, DO, PO_4 and alkalinity (Table-8)

Table-8- Correlation between the physicochemical parameters and benthic density in five stations of Langting stream:-

Parameters	Flow(m/s)	Air temp. (˚C)	Water temp(˚C)	TDS (µs/cm)	Conductivity (µs/cm	Turbidity (NTP)	pH	DO(ppm)	PO_4	Free CO_2 (mg/l)	Alkalinity (mg/l)	Ben den.
Flow(m/s)	1.00											
Air temp. (˚C)	0.07	1.00										
Water temp(˚C)	-0.21	0.96	1.00									
TDS(µs/cm)	0.47	0.60	0.45	1.00								
Conductivity (µs/cm)	-0.19	-0.62	-0.59	0.03	1.00							
Turbidity(NTP)	0.05	0.99	0.96	0.54	-0.64	1.00						
pH	0.24	0.44	0.33	0.90	0.37	0.39	1.00					
DO(ppm)	-0.51	0.17	0.33	-0.68	-0.63	0.24	-0.74	1.00				
PO_4	0.65	0.69	0.49	0.49	-0.62	0.72	0.29	0.02	1.00			
Free CO_2	0.79	0.35	0.16	0.45	-0.60	0.31	0.04	-0.19	0.60	1.00		
Alkalinity	-0.99	-0.19	0.08	-0.54	0.28	-0.16	-0.26	0.48	-0.69	-0.87	1.00	
Ben den	-0.61	0.66	0.80	-0.05	-0.38	0.70	0.04	0.64	0.20	-0.39	0.55	1.00

Diversity Indices: The diversity indices were calculated for the benthic macroinvertebrates of different sampling stations (Table-9). H (Shannon-Wiener Diversity index) of benthic macroinvertebrate in Langting river was ranged from 1.76 in winter at S4 to 2.22 in pre-monsoon at S1. D (Simpson's Diversity index) in Langting river was recorded minimum 0.81 at S4 in monsoon to a maximum 0.89 at S1 and S2 in pre-monsoon. Ma(Margalef Diversity index) in Langting river was recorded minimum with 1.30 in winter at S4 to a maximum of 2.06 in monsoon at S1 [Fig. nos.-4(a) to 4(c)].

Table 9- H (Shannon-Wiener Diversity index), D(Simpson's Diversity index), Ma(Margalef Diversity index) of Langting river:

Stations	H				D				Ma			
	Pre-monsoon	Monsoon	Post-monsoon	Winter	Pre-monsoon	Monsoon	Post-monsoon	Winter	Pre-monsoon	Monsoon	Post-monsoon	Winter
S1	2.22	2.2	2.13	2.11	0.89	0.88	0.87	0.87	1.89	2.06	1.99	1.88
S2	2.14	2.21	2.21	2.15	0.89	0.88	0.88	0.89	1.70	2.03	2.03	1.91
S3	1.94	1.92	1.95	1.91	0.85	0.82	0.84	0.84	1.83	1.90	1.86	1.76
S4	1.91	1.78	1.78	1.76	0.85	0.81	0.82	0.83	1.51	1.38	1.38	1.30
S5	1.81	1.89	1.90	1.90	0.83	0.84	0.84	0.84	1.28	1.56	1.56	1.47

Tolerance values for macroinvertebrates for application in Family Biotic Index of the species found in Langting stream(Table-10):

Table-10-Tolerance values for macroinvertebrates for application in Family Biotic Index of the species found in Langting stream:

Sl no.	Name of genus/species	Tolerance value	Very Intolerant of Pollution (VIP)	Moderately Intolerant of Pollution(MIP)	Very Tolerant of Pollution(VTP)
1	Dragonfly(nymph)	3	VIP		
2	Baetis sp.	4	VIP		
3	llyocoris cimicoides	5		MIP	
4	Lamellidens marginalis	6		MIP	
5	Maydelliathelphusa lugubris	6		MIP	
6	Melanoides tuberculata	6		MIP	
7	Paludomus(P) conica	6		MIP	
8	Pila globosa(right spiral)	6		MIP	
9	Tubifex tubifex	8			VTP
10	Orthetrum Sabina	9			VTP

FBI: The Family Biotic Index (FBI) of benthic macroinvertebrates has shown variation for different sampling stations of the Langting stream. The water quality varied seasonally at the sampling stations as shown in Table - 11.

Table 11 - Family Biotic Index of Langting River:

Station	FBI value	Water Quality	Degree of organic pollution
I	5.5	Good	Some organic pollution
II	5.3	Good	Some organic pollution
III	6.9	Fairly Fair	Fairly significant organic pollution
IV	7	Fairly Fair	Fairly significant organic pollution
V	7	Fairly Fair	Fairly significant organic pollution

Discussion:

Physicochemical parameters

Different physicochemical parameters are important in deciding the quality and productivity of an aquatic system. Every aquatic ecosystem has its own hydro-biological features, which are largely governed by the topography, geology and the climate regime of the region where it is located. The data recorded for physicochemical parameters showed remarkable variations in both physical and chemical parameters during different seasons but did not show much variation among the sampling sites.

The velocity of water had a direct and indirect effect on the aquatic benthic macro-invertebrate community. High river velocity supports more oxygen content and thus, more aquatic organisms. During the rainy periods the discharge is high than during the dry seasons. There is a tendency of the populations of the macro-invertebrates being high in the upland areas than in the lowland areas especially during the rainy seasons (Weatherly and Ormerod, 1990). The water temperature showed a declining trend from monsoon to winter in all stations. TDS is a very useful parameter indicating the chemical constituents of the water and can be considered as a generator of edaphic relations that constitute to productivity within the water body (Goher, 2002). The maximum TDS recorded during post-monsoon may be correlated to the increase in rate of evaporation as well as increase in dissolved salts in Electric conductivity is an indicative of the salt concentration and it can be measured. Greater the conductivity, greater is the quantity of ions such as Calcium, Chloride, Sodium, Magnesium, bicarbonates and carbonates in water. Thus it is the total amount of dissolved salts in water. There is a remarkable variation of conductivity of Langting river water ranging between 167.3 µS/cm (minimum) in post-monsoon and 233.27µS/cm (maximum) in monsoon. Turbidity is another factor which influences the distribution of aquatic organism to a great extent. The measure of cloudiness of water which is caused by suspended particles of clay, silt and other organic matter and by plankton and other macroscopic organisms that interfere with passage of light through water (American Public Health Association, 1998). The minimum and maximum values of turbidity were found to be 3.33 NTU(in monsoon) and 2.86 NTU(in winter)..Acceptable values of turbidity (2.21 NTU-5.05 NTU) obtained during the study period indicates less anthropogenic activities in the sampling sites

The pH of water is important because many biological activities can occur only with in a narrow range and it affects. The minimum and maximum values of pH river were found to be 7.30(in monsoon) and 8.03(in winter) respectively. pH regulates most of the biological processes and bio-chemical reactions. In a balanced ecosystem pH is maintained within the range of 5.5 to 8.5 (Chandrasekhar *et al.*, 2003). The minimum and maximum values of dissolved oxygen were found to be 5.06 mg/l(in post-monsoon) and 7.24 mg/l(in monsoon) respectively. Oxygen content of a water body is important for direct need of many organisms. Majority of chemical and biological processes undergoing in the water body also depend on the presence of oxygen. It is also essential to maintain the higher forms of biological life and balance the populations of various organisms. The cycling of phosphorus within lakes and rivers is dynamic and complex process, involving adsorption and precipitation reactions, interchange with sediments and uptake by aquatic biota (Borberg and Persson, 1988). The Langting river recorded the maximum and minimum value of phosphate as 0.04 mg/dl in pre-monsoon and 0.021 mg/dl in post-monsoon and monsoon respectively. Though carbon dioxide is readily soluble in water, very little carbon dioxide is present in sample because of the small amount of it being present in the atmosphere. Apart from this, decomposition of organic matter and the respiration of aquatic plants and animals also contribute to the free carbon dioxide levels. Alkalinity is a measure of the quantity of compounds that shift the pH to the alkaline side of neutrality.(above 7) or it is a measure of the capacity of water to neutralize acids. Raising the alkalinity always raises pH. If the alkalinity of water is too high, the water can be turbid, which inhibits the growth of under water plants. Too high alkalinity in the water causes raise in pH level, which in turn harmful to fish and other organisms. (Kamble *et. al.*, 2008). The maximum value of alkalinity in Langting river were estimated to be 162.96 mg/l in monsoon season and the minimum value was calculated to be 87.29 mg/l in winter season.

Benthic macroinvertebrate:

The use of living organisms for monitoring water quality originated in Europe and it is widely used throughout the world. Klemm *et al.*, 2002 developed methods and used macroinvertebrates as indicators of ecological conditions for streams in the Mid-Atlantic Highlands region. Experiences from USA and European programme have demonstrated that benthic macroinvetebrates are most useful in monitoring freshwater ecosystems.

In the present study, the order Mesogastropoda was found most diverse and relatively abundant in Langting river. The causes of fluctuations in insect abundance, dominance and distribution include macroclimatic and microclimatic in the availability of food resources.

Characteristically, the Langting river is dominated by group of macroinvertebrates such as *llyocoris cimicoides, Lamellidens marginalis, Maydelliathelphusa lugubris, Melanoides tuberculata, Paludomus(P) conica, Pila globosa(right spiral)* at S1, S2 and S5. These kinds of macroinvertebrates are moderately pollution sensitive organisms or somewhat pollution tolerant macroinvertebrates. They can survive in good quality and fair quality of water because their habitat requirements are not as strict as pollution sensitive organisms such as *Dragin fly(nymph)* and *Baetis sp.*. Hence according to Camago *et al.,* and Capitulo these macroinvertebrates indicate that the aquatic environment of S1, S2 of Langting river is moderately polluted.

On the other hand , the large abundance of very tolerant pollution species like *Tubifex tubifex Orthetrum Sabina* at S3 and S4 in Langting river indicate that the river is not clean at the specified stations.

Conclusion and recommendation:

The findings depict that the status of water quality of Langting stream is not very clean because its aquatic environment is slight to moderately polluted. . Long term biomonitoring of water quality of the stream coupled with socio economic reviews might provide clues for identifying the sources of stress and subsequently environment awareness can be disseminated. Failure to monitor the studied stream may result in health hazards to local inhabitants who use it for day-to-day domestic activities. Therefore, this study recommends that the relevant authorities should regularly monitor and control the source of pollutants. Further, the study recommends the adoption of biological indicators and their indices by pertinent authorities while assessing the condition of selected river.

No significant and comprehensive work has been put on record about the hill streams of Dima Hasao district till date. As such, present study is exercised as an initial attempt to summarize and tabulate results from biomonitoring of Langting stream of Dima Hasao district, Assam that has been undertaken. This study could *be* an advantage for environmentalists or policy makers to strategize the conservative measures for maintaining its ecological health and to arrest further deterioration of the selected stream.

References:

Aazami, J., KianiMehr, N., Zamani, A. (2019): Ecological water health assessment using benthic macroinvertebrate communities (case study: the Ghezel Ozan River in Zanjan Province, Iran). *Environmental Monitoring and Assessment*, **191,** 1-9. https://doi.org/10.1007/s10661-019-7894-1

Aazami, J., Maghsodlo, H., Mira, S.S., Valikhani, H. (2020): Health evaluation of riverine ecosystems using aquatic macroinvertbrates: a case study of Mohammad-Abad

River Iran. *International Journal of Environmental Science and Technology*, 7, 2637-2644.
https://doi.org/10.1007/s13762-020-02658-4

Akyildiz, G.K., Duran, M. (2021): Evaluation of the impact of heterogeneous environmental pollutants on benthic macroinvertebrates and water quality by long-term monitoring of the Buyuk Menderes river basin. *Environmental Monitoring and Assessment*, **193(5),** 280.
https://doi.org/10.1007/s10661-021-08981-8

American Public Health Association (APHA), American Water Works Association, and Water Pollution Control Federation. (1971): Standard methods for the examination of water and waste water. 13th ed. Washington, D.C. 874.

APHA (American Public Health Association) (1995): American water works association and water pollution control federation. Standard Methods Examination of Water and Waste water 19 th edition, New York U.S.A

Armitage, P.D., Moss, D., Wright, J.F. and Furse, M.T. (1983): The Performance of A New Biological Water Quality System Based On Macroinvertebrates Over a Wide Range Of Unpolluted Running Water Sites. *Water Research*.**17 (3)**: 333-347.

Arthington, A. H., Naiman, R. J., McClain, M. E. and Nilsson, C. (2010): Preserving the biodeverity and ecological services of rivers: new challenges and research opportunities, *Freshwater Biol*., **55,** 1–16.

Ashton, P.J. (2007): Riverine biodiversity conservation in South Africa: current situation and future prospects. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **17(5),** 441-445.
https://doi.org/10.1007/s13762-020-02658-4

Barathy, S., Sivaruban, T., Arunachalam, M., Srinivasan, P. (2021): Community structure of Mayflies (Insecta: Ephemeroptera) in tropical streams of Western Ghats of Southern India. *Aquatic Research***, 4(1),** 21-37.
https://doi.org/10.3153/AR21003

Bonada, N., Prat, N., Resh, V. and Statzner, B. (2006): Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. *Annual Review of Entomology*, **51,** 495-523.

Birk, S., Bonne, W., Borja, A., Brucet, S., Courrat, A., Poikane, S., Solimini, A., van de Bund, W.V., Zampoukas, N., Hering, D. (2012): Three hundred ways to assess Europe's surface waters: An almost complete overview of biological methods to implement the Water Framework Directive. *Ecological Indicator*, **18,** 31-41.
https://doi.org/10.1016/j.ecolind.2011.10.009.

Cairns, J. (Jr.) and Pratt, J. R. (1993): A history of biological monitoring using benthic macroinvertebrates. In Rosenberg, D. M. and Resh, V. H. (eds), Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York, 10-27.

Carter, J.L., Resh, V.H., Morgan, J.H. (2017): Macroinvertebrates as biotic indicators of environmental quality. In: Lamberti, G.A., Hauer, F.R. (Eds.), Methods in stream ecology (Third edition). Academic Press. 293-318.
https://doi.org/10.1016/B978-0-12-813047-6.00016-4

Camargo, J. A., Alonso, A., and De la Puente, M. (2004) Multimetric assessment of nutrient enrichment in impounded rivers based on benthic macroinvertebrates. Environmental **Monitoring and Assessment. 96: 233–249. [38] Capitulo, A. R., Tangorra, M., and Ocon, C. (2001)** Use of benthic macroinvertebrates to assess the biological status of Pampean streams in Argentina. Aquatic Ecology. 35, 109–119.

Chandrasekhar, J.S., Lenin Babu, K.and Somasekhar R.K. (2003): Impact of urbanization on Bellandur Lake, Banglore-A case study. *J. Environ. Biol*., **24,** 223-227. Edmondson W T, Ward and Whipple's Fresh Water Biology. 2nd Ed John Wily and Sons, New York, 1993. .

Edmondson, W.T. (1993): Ward and Whipple's Fresh Water Biology, 2nd Ed. John Wiley and Sons, New York, *Environmental Ecology*, **9,** 995-998,.

Eriksen, T.E., Brittain, J.E., Søli, G., Jacobsen, D., Goethals, P., Friberg, N. (2021): A global perspective on the application of riverine macroinvertebrates as biological indicators in Africa, South-Central America, Mexico and Southern Asia, *Ecological Indicators*, **126,** 1-17. https://doi.org/10.1016/j.ecolind.2021.107609

Extence, C.A., Chadd, R.P., England, J., Dunbar, M.J., Wood, P. J. and Taylor, E.D. (2013): The assessment of fine sediment accumulation in rivers using macroinvertebrate community response. *River Research and Applications*, **29,** 17-55. https://doi.org/10.1002/rra.1569.

Ganguly, I., Patnaik, L., Nayak, S. (2018): Macroinvertebrates and its impact in assessing water quality of riverine system: A case study of Mahanadi River, Cuttack, India, *Journal of Applied and Natural Science*, **10 (3),** 958-963. https://doi.org/10.31018/jans.v10i3.1817

Goher, M.A. (2002): Chemical studies on the precipitation and dissolution of some chemical elements in Lake Qarun, Ph.D. Thesis, Fac., of Sci., Azhar Univ. Cairo, Egypt, 153.

Hassan, M.A., Hogan, D.L., Bird, S.A., May, C.L., Gomi, T. and Campbell, D. (2005): Spatial and temporal dynamics of wood in headwater streams of the Pacific Northwest. *Journal of the American Water Resources Association*, **41,** 899–919.

Hellawell, J.M. (1986): Biological indicators of freshwater pollution and environmental management. In: Melanby K, Editor, Pollution Monitoring Series, New York: Elsevier Science Publisher Ltd., 1-558. https://doi.org/10.1007/978-94-009-4315-5

Jewitt, G. (2002): Can Integrated Water Resources Management sustains the provision of ecosystems goods and services? Physics and Chemistry of the Earth **27,** 887-895.

Kamble, P. N., Kokate, S. J., Aher, H. R. and Kuchekar, S. R. (2008): Seasonal variation in physicochemical parameters of Khadakwasala reservoir. *Rasayan J. of chemistry*, **1(1),** 63-67.

Klemm, D. J., Blocksom, K.A., Thoeny, W.T., Fulk, F.A., Herlihy, A.T., Kaufmann, P.R. and Cormier, S.M. (2002): Methods development and use of macroinvertebrates as indicators of ecological conditions for streams in the Mid-Atlantic Highlands Region. *Environ Monit Assess*. **78(2),** 169–212.

Li, L., Zheng, B., Liu, L. (2010): Biomonitoring and bioindicators used for River ecosystems: Definitions, approaches and trends. *Procedia Environmental Sciences*, **2,** 1510- 1524. https://doi.org/10.1016/j.proenv.2010.10.164

Mahmoud, M.A., Riad, S.A. (2020): Ecological studies on some aquatic insects in the Damietta branch, River Nile of Egypt as bioindicators of pollution. *Egyptian Journal of Aquatic Biology and Fisheries*, **24(4),** 57-76. https://doi.org/10.21608/EJABF.202095322

Margalef, R. (1958): Information theory in ecology. *Gen. Syst.*, **3,** 36-71.

Marzin, A., Archaimbault, V., Belliard, J., Chauvin, C., Delmas, F. and Pont, D. (2012): Ecological assessment of running waters: do macrophytes, macroinvertebrates, diatoms and fish show similar responses to human pressures? Ecological Indicators, **3,** 56–65. DOI 10.1016/j.ecolind.2012.03.010.

Mason, C. F. (1996): Biology of Freshwater Pollution: Longman, New York, 8-19.

Metcalfe, J. (1989): Biological Water Quality Assessment of Running Waters Based on Macroinvertebrate Communities: History and Present Status in Europe. *Environmental Pollution*, **60,** 101-139. https://doi.org/10.1016/0269-7491(89)90223-6

Metcalfe-Smith, J.L. (1994): Biological water quality assessment of rivers: use of macroinvertebrate communities". In *The rivers handbook. Vol. 2: hydrological* *and ecological principles* , Edited by: Calow, P. and Petts, G. E. 144–170. Oxford: Blackwell Scientific Publications.

Musonge, P.S., Boets, P., Lock, K., Ambarita, M.N.D., Forio, M.A.E., and Goethals, P.L. (2020). Rwenzori Score (RS): A benthic macroinvertebrate index for biomonitoring rivers and streams in the Rwenzori region, Ugenda, Sustainability, **12,** 10473. https://doi.org/10.3390/su12241047

Mustow, S.E. (2002): Biological monitoring of rivers in Thailand: Use and adaptation of the BMWP score. *Hydrobiologia*, **479,** 191-229.

Pennak, R.W. (1989): Fresh invertebrates of the United States; Protozoa to Mollusca. Johan Wily and Sons. *INC Pleidae*. 535-558,

Shannon, C. E. and W. Weaver (1949): The Mathematical Theory of Communication. University of Illinois Press, Urbana, Illinois. 144.

Simpson, E.H. (1949): Measurement of Diversity. *Nature,* **163,** 688. http://dx.doi.org/10.1038/163688a0

Resh, V. H. (2007): Multinational, freshwater biomonitoring programs in the developing world: lessons learned from African and Southeast Asian river surveys. *Environmental Management*, **39(5),** 737–748. doi:10.1007/s00267-006-0151-8.

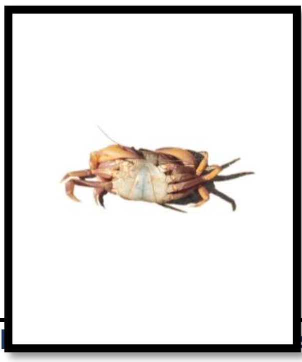
Venkatesharaju K, Ravikumar P, Somashekar RK and Prakash KL (2010): Physico-chemical and bacteriological investigation on the river Cauvery of Kollegal stretch in Karnataka. *Kathmandu Univ J Sci Eng Technol*, **6,** 50–59.

Weatherley N.S. and Ormerod S.J. (1990): The constancy of invertebrate assemblages in soft-water streams: implications for the prediction and detection of environmental change. *Journal of Applied Ecology*, **27,** 952–964.

Dragonfly nymph

Baetis sp.

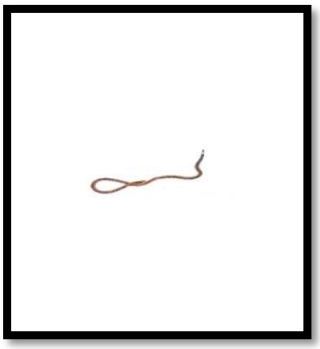
Ilyocoris cimicoides .



Lamellidens marginalis *Maydelliathelphusa lugubris* *Pila globasa*

Paludomus conica

Melanoides tuberculate



Tubifex tubifex

Orthetrum Sabina

Fig-3-Graphical representation of Benthic Macroinvetebrates found in Langting river:

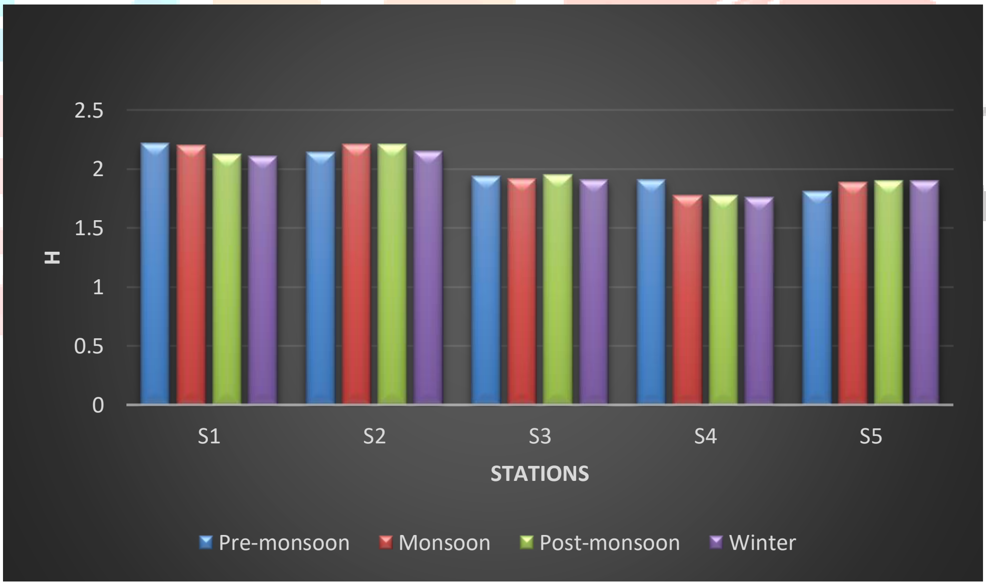


Figure-4(a)- Seasonal Variation of Shannon-Weiner Diversity Index

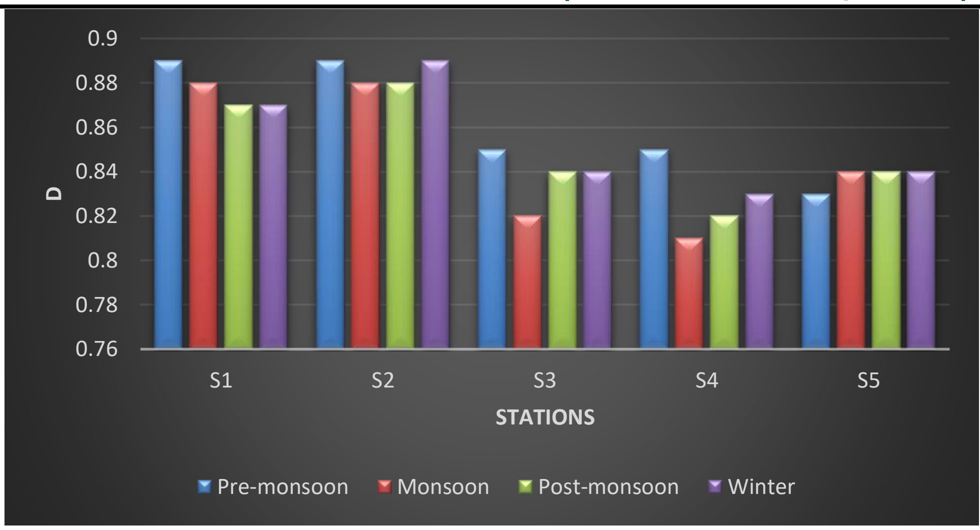


Figure-4(b)- Seasonal Variation of Simpson's Diversity Index

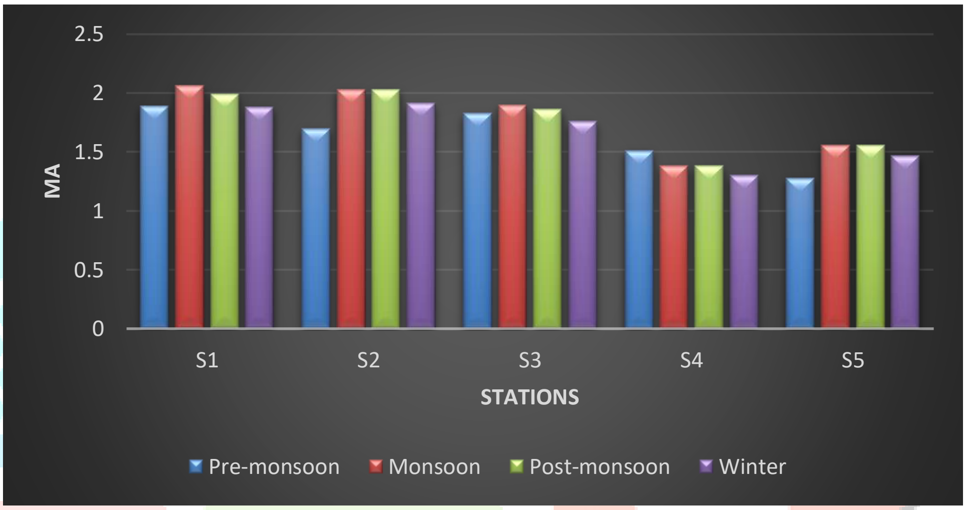


Figure-4(c)- Seasonal Variation of Margalef Diversity Index